Proposed Approach for Determination of Intent Information Exchange Requirements

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Approach: Planned flight path trajectory parameters or intent information broadcasts may be used by other airborne or ATC recipients to de-conflict airspace. Near term altitude and heading information (TSRs) may be used to augment tactical or state vector data to reduce false conflict alert rates. Longer term trajectory change information (TCRs) may be used to optimize required changes in the planned flight path in order to resolve detected airspace conflicts. De-confliction support can enhance safety of flight since the de-confliction process adds another layer of alert warning, thus often avoiding the need for a more aggressive tactical maneuver based on state vector data alone which might otherwise be required later in time to avoid a loss of minimum required separation.

A suitable approach to defining operational requirements for exchange of intent information might then be based on a determination of how a failure in exchange of this information (or acceptance of erroneous information) reduces the efficacy of the supported de-confliction application. A loss in the strategic planning time frame when the available intent information is not current is proposed as the basis for this evaluation standard. For example, assume two approaching aircraft are separated by R nmi when one of them makes a change in planned trajectory that will lead to a conflict if not resolved. Further assume the separation has been reduced by dR nmi before the other aircraft receives this new information and makes an adjustment in his planned trajectory that will resolve the conflict. The potential severity in this path adjustment has increased by dR/R in comparison to what it might have been if the modification had been made when the separation was R rather than R-dR. If the closing speed is Vt, then the loss in strategic planning, or look-ahead, time is Tu = dR/Vt. In a broadcast system, if dR/R is an acceptable loss in planning efficacy and Vt is the maximum expected closing rate, then Tu may be considered the required intent information refresh, or update, rate since the intent change can occur at any time.

Proposed Air-Air Intent Update Interval: Assume a fractional loss in look-ahead time no greater than "f" is acceptable with a probability of 5%. From the above, we then have the 95^{th} percent update rate for TSR and TCR information reception given by Tu = f*R/Vt. With a maximum expected closing speed of 1200 kts and a separation of R nmi, then

$$Tu = f*R*3600/1200 \text{ seconds, or}$$

$$Tu = f*3*R \text{ seconds.}$$

This 95th percent intent received update interval for a value f = 0.15 is plotted in Figure 1 as a function of separation range along with the corresponding 95th percent state vector update interval. Notice this curve supports the near term higher update rates needed for TSR data, but permits lower update rates for the longer planning horizon associated with TCR data. Since shorter separation ranges rely more heavily on state vector updates than intent information, we can limit the minimum value of Tu to 12 seconds.

Intent Scenarios: Characteristics of this model are illustrated by several examples based on the most stressing scenario of two closing aircraft that expect to pass with a safe separation until one, termed the threat, transmits an intent to cross the path of the other, the victim. As stated above, the operational benefit of the exchange of intent data is then assessed by determining how long it takes for the victim to detect this threat and adapt his planned flight path accordingly.

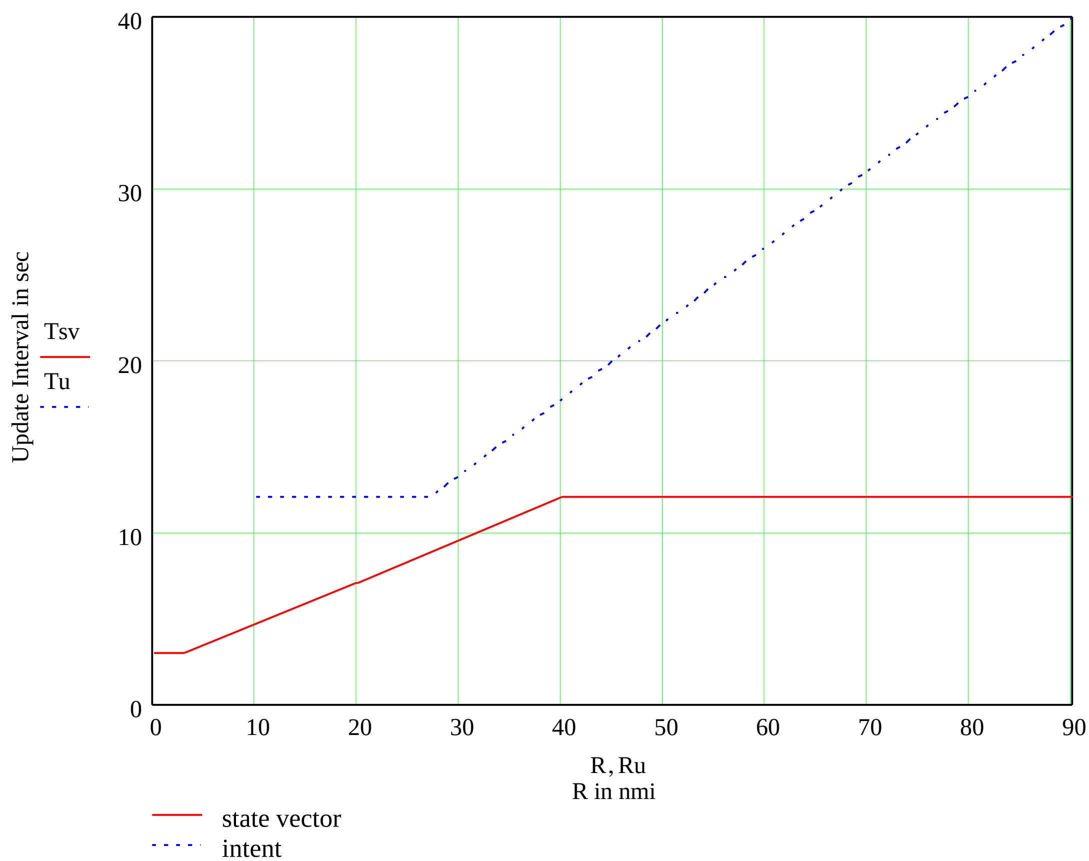

Figure 1 Required 95th percential update intervals in seconds for state vectors (solid line) and intent TSR/TCR information (dotted line) as a function of air-air separation range, R nmi. Fractional separation loss per update interval of f = 0.15 assumed with Tu => 12 sec.

Initially, the two aircraft are separated by the maximum air-air coverage range, Rm. With threat aircraft velocity, Vt, and victim aircraft velocity, Vv, the total closing rate is vc = Vt + Vv and the time to closest point of approach is Tca = Rm/vc. The maximum range from the threat to the potential intent conflict point is RI = Tca*Vt, and the range from the victim to this point is Rvm = Rm – RI. Notice that intent data much further ahead of the threat than RI is of no interest to this particular victim since the victim will have already passed this more distant point before the threat arrives there. Similarly, data much closer to the threat than RI is of no interest to this particular victim since the victim will not yet have reached this point when it has been passed by the potential threat. On a pair-wise head –to-head basis, the normalized region of interest to the potential victim is given by the above relationships as Rv = R(1 – Vt/vc). The time to go to this intent point of potential conflict is Ttg = RI /vt.

As stated above, if the fractional reduction in range during an update interval is “f”, the 95% update interval is Tu = f*R/vc (Tu => 12 sec), and the corresponding range reduction is dR = Tu*vc. As a matter of interest, observe that for independent tries, the probability that the data is received within two adjacent update intervals is 99.75%.

The most demanding case is when each of the aircraft in a head-to-head encounter have the maximum expected velocity of 600 knots. For the Figure 1 value of f = 0.15 and these velocities, the successive scenario snapshots given in the first example below result. The following two example show less demanding scenarios where one of the two aircraft has a velocity of only 300 knots while the other still has 600 knots. The last example illustrates the behavior in the most demanding case when the value of “f” is 0.25.

$i := 0..9$ $Rm = 100$ $Vt = 600$ $Vv = 600$ $RIm = 50$ $f = 0.15$

Separation (nmi) $R_i =$	95% update interval (sec) $Tu_i =$	Separation reduction (nmi) $dR_i =$	Range to TCR (nmi) $RI_i =$	Victim range to TCR (nmi) $Rv_i =$	Time to go (seconds) $Ttg_i =$
100	45	15	50	50	300
85	38.3	12.8	42.5	42.5	255
72.3	32.5	10.8	36.1	36.1	216.8
61.4	27.6	9.2	30.7	30.7	184.2
52.2	23.5	7.8	26.1	26.1	156.6
44.4	20	6.7	22.2	22.2	133.1
37.7	17	5.7	18.9	18.9	113.1
32.1	14.4	4.8	16	16	96.2
27.2	12.3	4.1	13.6	13.6	81.7
23.2	12	4	11.6	11.6	69.5

$i := 0..9$ $Rm = 100$ $Vt = 300$ $Vv = 600$ $RIm = 33.3$ $f = 0.15$

Separation (nmi) $R_i =$	95% update interval (sec) $Tu_i =$	Separation reduction (nmi) $dR_i =$	Range to TCR (nmi) $RI_i =$	Victim range to TCR (nmi) $Rv_i =$	Time to go (seconds) $Ttg_i =$
100	60	15	33.3	66.7	400
85	51	12.8	28.3	56.7	340
72.3	43.4	10.8	24.1	48.2	289
61.4	36.8	9.2	20.5	40.9	245.6
52.2	31.3	7.8	17.4	34.8	208.8
44.4	26.6	6.7	14.8	29.6	177.5
37.7	22.6	5.7	12.6	25.1	150.9
32.1	19.2	4.8	10.7	21.4	128.2
27.2	16.3	4.1	9.1	18.2	109
23.2	13.9	3.5	7.7	15.4	92.6

$i := 0..9$ $Rm = 100$ $Vt = 600$ $Vv = 300$ $RIm = 66.7$ $f = 0.15$

Separation (nmi) $R_i =$	95% update interval (sec) $Tu_i =$	Separation reduction (nmi) $dR_i =$	Range to TCR (nmi) $RI_i =$	Victim range to TCR (nmi) $Rv_i =$	Time to go (seconds) $Ttg_i =$
100	60	15	66.7	33.3	400
85	51	12.8	56.7	28.3	340
72.3	43.4	10.8	48.2	24.1	289
61.4	36.8	9.2	40.9	20.5	245.6
52.2	31.3	7.8	34.8	17.4	208.8
44.4	26.6	6.7	29.6	14.8	177.5
37.7	22.6	5.7	25.1	12.6	150.9
32.1	19.2	4.8	21.4	10.7	128.2
27.2	16.3	4.1	18.2	9.1	109
23.2	13.9	3.5	15.4	7.7	92.6

$i := 0..9$ $Rm = 100$ $Vt = 600$ $Vv = 600$ $RIm = 50$ $f = 0.25$

Separation (nmi) $R_i =$	95% update interval (sec) $Tu_i =$	Separation reduction (nmi) $dR_i =$	Range to TCR (nmi) $RI_i =$	Victim range to TCR (nmi) $Rv_i =$	Time to go (seconds) $Ttg_i =$
100	75	25	50	50	300
75	56.3	18.8	37.5	37.5	225
56.3	42.2	14.1	28.1	28.1	168.8
42.2	31.6	10.5	21.1	21.1	126.6
31.6	23.7	7.9	15.8	15.8	94.9
23.7	17.8	5.9	11.9	11.9	71.2
17.8	13.3	4.4	8.9	8.9	53.4
13.3	12	4	6.7	6.7	40
9.3	12	4	4.7	4.7	28
5.3	12	4	2.7	2.7	16

Proposed ATC Intent Update Interval: Ground ATC use of ADS-B intent broadcasts differs in some respects from that of other airborne users since ATC generally has access to additional planning information. Typically, enroute ATC airspace de-confliction uses a ten minute conflict prediction alert time. If ADS-B intent broadcasts are used to enhance this prediction capability, or convey desired trajectory information to ATC, then a 600 kt aircraft speed corresponds to a 100 nmi look-ahead range. If the above air-air level of information delivery degradation is also acceptable to ATC, then a TCR update interval of 1.5 minutes or 90 seconds results.

If TSR ADS-B broadcasts functionally replace down linked heading and altitude data that has previously been associated with the Mode-S Enhanced Surveillance concept, then a comparison to expected Mode-S behavior is a useful baseline for update requirements. If the requested Mode-S data is delivered on the next scan, TSR updates of 5 seconds are required over the 60 nmi TMA coverage area, and updates of 12 seconds are required over the nominal 180 nmi enroute area. Further coordination with ATC users is needed to refine this definition of ground use of ADS-B intent data.